

VALIDATION AND RESEARCH UTILIZATION OF THE NRL REGIONAL MODEL FOR THE U.S. WEST COAST

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LONG-TERM GOALS

Our long-term goal is to understand the spatially and temporally varying circulation in the California Current System. One aspect of the circulation is a quantitative description of the spatial and temporal variability of currents and water properties, including the time-varying mean fields and their higher order statistics. Another aspect is the quantification of the momentum and heat balances that govern that variability.

OBJECTIVES

In this project, we focus on the regional numerical circulation model under development by the U.S. Navy at NRL, as applied to the circulation of the California Current.

Our specific objectives are:

- (1) To determine how well the regional nested NRL model reproduces the features and statistical fields as observed by satellite data and field surveys, with specific attention to:
 - (a) the seasonal development of the spatial structure of surface height and velocity fields;
 - (b) the 3-D structure of meandering equatorward jets and mesoscale eddies;
 - (c) the existence and properties (width, strength, continuity, eddy generation) of the poleward undercurrent along the continental slope;
 - (d) the existence and properties of separating coastal jets;

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(e) the seasonal development of the 2-D spatial structure in Eulerian surface eddy statistics (velocity variances, eddy kinetic energy [EKE], eddy momentum fluxes, and principal axis ellipses);
(f) the vertical structure of the same Eulerian eddy statistics, as determined from moored current meters; and
(g) the spatial structure of Lagrangian eddy statistics, as calculated from surface drifter trajectories.

(2) To use the model, in combination with the satellite and field data, to understand the processes that control transports in the large-scale eastern boundary current and the more detailed circulation over the shelf and slope; and

(3) To develop the methodology for nesting high-resolution models of circulation over the west coast continental shelf and slope, to test the shelf models by comparison with observations, and to use the nested models to study the dynamics of west coast shelf circulation processes.

APPROACH

Navy modelers at NRL are developing a regional, coastal ocean circulation model that can be implemented in any part of the global ocean, nested within the Navy's global ocean circulation model. One of the initial locations chosen for development and testing of the nested model is the U.S. west coast from 30N--50N, where a great deal of observational data exists in the California Current System (CCS). This model will continue to be used and expanded in the CCS region under an internal NRL ARI with John Kindle as PI, including an ecosystem and optical submodel.

Our general approach is to evaluate the realism of the NRL regional model by comparing statistical analyses of the model output fields to identical analyses of satellite and in situ fields from the same region. We will also evaluate the ability of the regional model to provide boundary conditions for a nested, very high resolution nearshore model.

The satellite data from this period consist primarily of altimeter data, for comparison to model surface height or pressure fields. Satellite sea surface temperature (SST) fields will also be compared to model SST fields. The highest resolution altimeter data during periods of field studies come from October 1992 to December 1993, when both TOPEX/POSEIDON (T/P) and ERS-1 were in exact repeat orbits. The period from mid-1995 to the present has similar coverage (T/P plus ERS-2).

Field data from these periods include surveys in the ONR EBC project off northern California in 1993 and surveys off Cape Blanco (43 N) during the NSF investigation of a separating coastal jet (SCJ) in 1994 and 1995. Drifters released in these programs extend from 1993--1995. Moorings deployed in the EBC project collected two-years of data from 1993-1994.

The approach taken to investigate very high-resolution nested models is to use the stratified, hydrostatic primitive equation Blumberg-Mellor model (POM) to run idealized simulations at high resolution. We then use a coarser model with nested high resolution submodels to investigate the ability of alternate nesting procedures to recapture important physical features of the coastal circulation. These features include wind-forced Ekman transport in the surface layer, bottom boundary layers over sloping topography, and upwelling or downwelling fronts that intersect the nested grid boundary. The model configuration consists of idealized continental shelf topography within a periodic channel. The numerical experiments involve wind-forcing that is either spatially varying or uniform. Experience gained from the idealized numerical experiments will be used to nest a high resolution coastal circulation model within the Navy's Pacific West Coast model. The area of enhanced resolution (37.25 N - 40 N) includes the region between Point Arena and Point Reyes - the site of the Coastal Ocean Dynamics Experiment.

WORK COMPLETED

The statistical comparisons of fields from the model to fields from satellite data or in situ surveys require: (1) analyses of the satellite and in situ fields; and (2) access to the model output fields, for similar analyses.

An initial evaluation of the altimeter data has been completed (Strub et al., 1997). Statistical analysis of the altimeter and SST data has been completed and submitted for publication (Strub and James, 1997). An initial evaluation of the in situ data has also been completed and submitted for publication (Shearman et al. 1997).

Model nesting methods have been evaluated in both one-way and two-way interactions in the idealized simulations, including different spatial interpolation schemes (conservative and non-conservative), relaxation zones, and filtering. Accuracy was assessed by comparison of the solutions resulting from different nesting procedures with reference solutions from a uniform fine grid. Work on nesting within the Navy Pacific West Coast model is in progress. A grid is being configured for the CODE region in a one-way nest with the Navy Pacific West Coast model. J. Pullen has spent time at NRL, working closely with the NRL modelers to learn how to run the regional model remotely. One model run has been completed and plans for future runs are in place.

RESULTS

Analysis of the satellite altimeter surface height and temperature fields were used to define the seasonal surface circulation in the California Current System. In spring and summer, an equatorward jet develops next to the coast, with a latitudinal structure that responds to the equatorward alongshore winds. This jet moves offshore from spring to fall and contributes eddy kinetic energy to the deep ocean, which appears to dissipate in place east of approximately 130 W. In winter, a poleward Inshore Countercurrent is found in the 100 km next to the coast north of 35 N--37 N. Eddy statistics show that most of the eddy kinetic energy (EKE) is confined to the region within 750 km of the coast, inshore of the

“eddy desert” found farther offshore. Along altimeter tracks 250 and 500 km offshore, the greatest EKE is found in spring and summer, with scales of 250--300 km, the scales of the dominant eddies and meanders in the jet. At 750--1000 km offshore, EKE is maximum in fall and winter and the scales are smaller. A sequence of snapshots from October 1992 to October 1993 shows details of the jet and eddy system over one complete annual cycle (Strub and James, 1997) on scales of 50--2000 kilometers. Definition of the circulation patterns in the California Current on these scales has not been previously possible using field data.

On a smaller scale, in situ, high resolution SeaSoar data show a density front at a depth of 70-100 m with strong cyclonic curvature. The geostrophic velocity fields, referenced to the ADCP data at 200 m, show a surface-intensified jet (0.8-1.0 m/s) that follows the density front through a cyclonic meander. Relative vorticities within the jet are large, ranging from $-0.4f$ to $+1.0f$, where f is the local Coriolis parameter. The SeaSoar density and ADCP velocity data are used to diagnose vertical velocity via the Q-vector form of the quasigeostrophic omega equation. The diagnosed vertical velocity field shows maximum velocities of 40-45 m/d and is characterized by horizontal length scales of 20-30 km. The high resolution in the fields is obtainable only through combined SeaSoar and ADCP data and is necessary to resolve the small-scale shears involved in these calculations. The NRL model output will be analyzed in a similar manner and compared to the EBC survey results, to determine how well the model reproduces the observed California Current mesoscale features. Direct comparisons will be made between the observed and modeled minimum and maximum buoyancy frequency (N), velocity, relative vorticity, and vertical velocity.

Evaluation of the effects of nesting, using a number of different idealized simulations, shows that nesting reduces the rms error compared to the reference solution. The relative success of the various nesting methods depends on the type of simulation. In a scenario with no alongshore variations in topography or wind-forcing (which should result in an alongshore-uniform response), the ability of the coarse grid to resolve the flow fields is found to be important for accurate representation of the cross-shelf velocity on the nested grid.

IMPACT/APPLICATIONS

The Navy is developing this relocatable regional model for global operational use. The same model is planned to be used as NOAA's operational coastal ocean forecast model off the west coast. Fields from the model will be used by the Coast Guard for search and rescue efforts, by fisheries managers, and many others, including academic researchers. Given this level of use for the model output fields, it is vital to quantify the errors in the model fields, so that model fields be better interpreted.

TRANSITIONS

As stated above, the model will be used operationally by many agencies and individuals. The results from our validation efforts will also become a part of that operational model deployment, in the form of estimates of model uncertainty.

RELATED PROJECTS

This work is being carried out in direct collaboration with the modelers at the NRL, primarily with John Kindle and his coworkers. Strub and James are also interacting with B. Semtner and R. Tokmakian at the Naval Postgraduate School, planning similar model-altimeter comparisons. As described above, the NRL model will be used in many locations by the Navy and along the U.S. west coast by NOAA. Our efforts will thus help to validate and guide improvements in operational models that will be used both by the Navy for military purposes and by NOAA for civilian purposes. Beyond model validation, our efforts will provide continued analysis of data sets collected during projects sponsored by ONR and NSF. Analysis of satellite altimeter data will augment the analysis conducted with NASA funding. Analysis of the circulation in the California Current will also help in planning research in the U.S. GLOBEC program on the North East Pacific, which is just beginning. Both Strub and Barth are members of (different) projects in the GLOBEC program. The nested modeling will also help John Allen's high resolution modeling effort off Oregon (part of the U.S. CoOP effort along the U.S. west coast).

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The satellite analysis of the circulation in the California Current can be found on Strub's research page on the Physical Oceanography home page of the OSU College of Oceanic and Atmospheric Sciences web site.

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